2240

HERBICIDE BASICS FOR USE IN RANGE MANAGEMENT

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE - NORTHERN REGION

DIVISION OF RANGE AND WILDLIFE MANAGEMENT

ISSUED MAY 1970

CAUTION

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key -- out of the reach of children and animals -- and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U. S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

Page

INTRODUCTION.......... 1
FUNGICIDES.......... 1
INSECTICIDES.......... 1
    Organic phosphorus insecticides.......... 1
    Chlorinated hydrocarbons.......... 2
    Carbamate insecticides.......... 2
    Inorganic insecticides.......... 2
    Botanical insecticides.......... 2
RODENTICIDES.......... 2
HERBICIDES.......... 2
HERBICIDE NAMES.......... 3
    Trademark or trade name.......... 3
    Chemical name.......... 3
    Common name.......... 3
HERBICIDE REGISTRATION AND LABELING.......... 3
CLASSIFICATION OF HERBICIDES.......... 4
    Foliage herbicides.......... 5
    Soil sterilants.......... 5
HERBICIDE FORMULATIONS.......... 6
    Solutions.......... 7
    Emulsions.......... 7
    Wettable powder.......... 7
    Granules or pellets.......... 8
    Dusts.......... 8
HERBICIDE CONCENTRATION.......... 8
HERBICIDE SELECTIVITY.......... 9
    Morphological or structural differences.......... 9
    Absorption of herbicides.......... 9
    Translocation differences.......... 9
    Physiological differences.......... 9
HERBICIDES IN SOIL.......... 9
    Microbial decomposition.......... 10
    Chemical decomposition.......... 10
    Adsorption to soil colloids.......... 10
    Leaching.......... 10
    Volatility.......... 10
    Photodecomposition.......... 11
DRIFT AND VOLATILITY OF HERBICIDES.......... 11
    Spray drift.......... 11
    Spray volatility.......... 11
CALCULATIONS FOR HERBICIDE APPLICATIONS.......... 12
HERBICIDE SAFETY.......... 13
FIVE RIGHTS FOR HERBICIDE USE.......... 14
TERMS.......... 16
HANDY REFERENCES.......... 18

HERBICIDE BASICS FOR USE IN RANGE MANAGEMENT

INTRODUCTION

The past 25 years have been characterized by increased emphasis on pesticides. Initial emphasis concerned rapid introduction of new pesticides and their wide-scale use as primary methods of control. Recently, much attention has been directed to the effects of pesticides on the environment, as well as to their development and use.

The word "pesticide" has acquired connotations ranging from the menacing to the magical. It is quite all inclusive and often misunderstood. Similarly, individual pesticides, such as the insecticide DDT and the herbicide 2,4-D are sometimes confused. This is understandable since there are approximately 900 basic chemical compounds used to formulate more than 60,000 registered brands of commercial products.

Pesticides can be classified according to purpose and may be defined that way. Some of the more common are fungicides, insecticides, rodenticides, and herbicides.

FUNGICIDES - Any substance or mixture of substances intended to prevent, destroy, repel, or mitigate any fungi. Fungi are non-chlorophyll bearing lower order plants such as rusts, smuts, mildews, molds, and yeasts. Some fungicide classes are dithiocarbamates (ferbam, zineb, maneb, mabam), organic mercury compounds (ethyl mercury phosphate, phenyl mercury acetate), and pentachlophenol. These are used as fungicides on fruit and vegetable crops, and turfs; and as a seed dressing to prevent seed-borne diseases in grain and other crops. Pentachlorophenol is used as an insecticide, herbicide, fungicide, and wood preservative.

INSECTICIDES - Any substance or mixture of substances intended to prevent, destroy, repel, or mitigate insects. Insecticides are among the most widely used and most controversial pesticides. The properties of toxicity and persistence of insecticides, as well as other pesticides, determine the range of effectiveness and how long they remain in the ecosystem. These properties are sometimes desirable from a pest control standpoint, but make the same insecticide undesirable in such respects as biodegradability and rapid residue accumulation in the biological food chain. This gives rise to much of the controversy. Three chemical groups of insecticides are particularly important.

1. Organic phosphorus insecticides - This is a rather large insecticide group, similar in chemical structure, and considered phosphoric acid derivatives. There is a wide toxicity variation to animals. Some of the most deadly compounds are included in this group. A few of the more familiar names are malathion, parathion, dibrom (Naled), diazinon, and di-syston. Common uses are control of many insects on fruits, vegetables,

field crops, flowers, and ornamentals; fly, mosquito, lice, and mite control on animals, animal premises, poultry and poultry houses, homes and surrounding areas.

2. Chlorinated hydrocarbons - These insecticides have in common the chemical composition implied in the group name. They are sometimes referred to as organochlorines. Residues of these chemicals may be retained and stored in animal tissue. They are persistent in the soil. In this group, DDT has probably been most widely used. Others are toxaphene, chloradane, aldrin, dieldrin, endrin, and heptachlor. Uses are similar to those listed for the organic phosphates.

3. Carbamate insecticides - The carbamates are a smaller, lesser known group but are still important against insecticide pests of fruit, nuts, vegetables, forage crops, cotton, and forest and range land. Zectran, dimetan, pyrolan, propamat, and carbaryl are carbamate insecticides.

4. Inorganic insecticides - This is an old-time group but is still used. Common members of this group are the arsenic, barium, boron, copper, mercury, sulphur, zinc, and elemental phosphorus compounds.

5. Botanical insecticides - Botanical compounds are a diverse group, having only their natural plant origin in common. Pyrethrum and allethrin are two extensively used toxins in sprays, dusts, and aerosols against a wide variety of insects. Others of the group are nicotine, rotenone, and anabasine.

RODENTICIDES - Any substance or mixture of substances intended to prevent, destroy, repel, or mitigate rodents or other vertebrate animals which have been declared pests. The rodenticides differ widely in their chemical nature. Some, such as strychnine, have been around for a long time. Sodium fluoroacetate (1080) is one of the most hazardous rodenticides available. Warfarin and Pival are chemicals commonly used. Others are calcium cyanide, carbon disulphide, thallium sulfate, and yellow phosphorus. Rodenticides are usually prepared as food or liquid baits to control mice, rats, roaches, other rodents, and predators in general. There is some danger to wildlife, principally from improper distribution. Birds are less susceptible than mammals to most rodenticides due to digestive system peculiarities.

HERBICIDES - Any substance or mixture of substances intended to prevent, destroy, repel, mitigate, or inhibit growth of plants.

The use of herbicides is important in range management resource programs concerned with vegetation manipulation and plant control. Other pesticide groups are equally important in other fields, as suggested in group names. These find only occasional use in range management for work such as grasshopper, grassbug, or predatory animal control.

In order to minimize threat of pollution and to accomplish the most effective results at least cost, some basic knowledge of herbicides is

not only desirable, but is essential for those doing range management work. The material written about herbicides is voluminous, often technical, and may even be uninteresting without some basic understanding. For people working with herbicides for the first time, or for those who occasionally use herbicides but are not constantly working with them, a quick orientation, easily mastered, is helpful. With this basic outline, an individual can then build on his knowledge as his interest or job requires.

HERBICIDE NAMES

1. Trademark or trade name - Name under which products are advertised and sold. If several manufacturers sell the product, there will be many trade names. Examples: Weedone 638, Weedar 64, DMA-4.

2. Chemical name - Chemical name of active ingredients. This will not vary on labels of different companies unless the active ingredient is formulated in a different way. Example: 2,4-dichlorophenoxyacetic acid.

3. Common name - Short name or abbreviation for the active ingredient which is accepted by the Weed Science Society of America. Example: 2,4-D.

HERBICIDE REGISTRATION AND LABELING

Federal law requires that all herbicide products be registered with the U. S. Department of Agriculture before they can be marketed in interstate commerce. Before registering the product, the Department requires the manufacturer to provide scientific evidence that the product (1) will be effective against the pest or pests listed on the label; and (2) will not injure humans, crops, livestock, and wildlife when used as directed.

The herbicide label contains the following information:

1. Trade name.

2. Chemical name of the active ingredient.

3. Concentration of active ingredient.

    a. Pounds per gallon.

    b. Percent based on dry weight.

4. Instructions for use. This may cover a wide variety of uses, each with different suggestions for rates, method of application, and time of application. It is illegal and usually unsafe to use an herbicide for any situation not described on the label.

5. Safety and use precautions.

6. Manufacturer and address.

CLASSIFICATION OF HERBICIDES

It is impossible to make a rigid classification of herbicides. On the basis of use, herbicides are grouped into selectives and nonselectives; on the basis of mode of action into contact, translocated, and sterilant chemicals. Selective herbicides are those that kill certain plants without seriously injuring the desirable plants among which they are growing. Nonselectives kill vegetation with little discrimination. Each chemical compound that has herbicidal properties has particular characteristics, and as a result, many herbicides would fit into more than one place in any classification. A comprehensive classification would of necessity be based on herbicide chemistry. This becomes complicated and complex with the many groupings. Worthy of special mention, however, is one major group of organic herbicides of particular interest in range management because of their selectivity and outstanding ability to translocate within plants. This is the phenoxyaliphatic acids group (phenol derivities) which includes 2,4-D, 2,4,5-T, MCPA, micoprop, 2,4-DB, silvex, dichloroprop, MCPB, and 2,4,5-TB.

Following is a simple herbicide classification:

1. Foliage herbicides
    a. Contact herbicides
    b. Translocated herbicides
        (1) Broadleaf weed killers
        (2) Grass killers
2. Soil sterilants
    a. Little soil residual
    b. Long soil residual
        (1) Broadleaf weed killers
        (2) Grass killers
        (3) Broadleaf and grass killers

1. Foliage herbicides - Herbicides applied to top growth of plants.

a. Contact herbicides - These herbicides kill plant parts that are covered with spray. The visual effects usually appear within a few hours after treatment. Whether the plant dies or recovers depends on whether it has a protected growing point. There is little if any soil residual. Some of these herbicides move in the plant after absorption. These herbicides are used for rapid killing of weeds in places where soil residual is objectionable. They are mixed with soil sterilants to give rapid top kill of existing vegetation. Examples: herbicidal oils, dinitrophenols, petrachlorophenol, paraquat, and ammonium sulfamate (Ammate).

b. Translocated herbicides - Herbicides that are absorbed into plants by the leaves, stems, or roots, and move to and kill growing points, such as buds and root tips.

(1) Broadleaf weed killers - The phenoxy herbicides and one substituted benzoic acid are the most common herbicides in this group. These readily translocated herbicides are absorbed through both foliage and roots. At usual rates of application for foliage treatments, soil residual is from 1 to 4 weeks. The short soil residual precludes use of these herbicides as soil sterilants. They kill plants by upsetting the balance between synthesis and utilization of food. These herbicides are used as foliage sprays for a variety of annual and perennial herbaceous and woody broadleaf plants. Each herbicide of this group has specific characteristics which make it suitable for killing certain plants. Examples: 2,4-D, 2,4,5-T, MCPA, silvex, 2,4-DB, and dicamba (Banvel).

(2) Grass killers - The only herbicide in this group is an aliphatic acid. It is absorbed by foliage and roots and may persist in the soil for 1 to 3 months. This chemical precipitates proteins. This characteristic may be related to its effectiveness as an herbicide. It is used as a foliage treatment to control a large variety of annual and perennial grass plants. Usually more than one application is required to control perennial grass weeds. Example: dalapon (Dowpon).

2. Soil sterilants - Herbicides that are applied to and act primarily through the soil.

a. Little soil residual - Soil persistence is usually from 1 to 3 weeks. These chemicals are sometimes referred to as soil fumigants and are very toxic to all forms of plant and animal life including weed seed and fungus spores. They are generally used to fumigate seedbeds for nursery stock and areas such as golf greens and football fields where weed and disease-free turf needs to be established rapidly. Examples: methyl bromide, carbon disulfide, and chloropicrin.

b. Long soil residual - These materials usually persist in soil from 1 to 3 years.

(1) Broadleaf weed killers - Herbicides in this group are a benzoic acid, picolinic acid, phenylacetic acid, and a benzyloxypropanol. These chemicals kill plants by upsetting internal metabolism similar to the phenoxy herbicides. These herbicides are usually water soluble and leach up to 6 feet into the soil where they are absorbed by roots. Foliage uptake may occur, but kill of perennial plants is usually by root absorption. High dosages in the soil will prevent growth of both annual grasses and broadleaf weeds. Perennial grasses are not usually killed. These herbicides are used to kill deep-rooted perennial broadleaf weeds such as field bindweed. Examples: 2,3,6-TBA (Benzac 1281, Trysben 200, and Benzabor); picloram (Tordon formulations and Borolin); fenac (Fenac); and 2,3,6-trichlorobenzyloxypropanol (Tritac).

(2) Grass killers - An aliphatic acid, trichloroacetic acid is the only herbicide available in this group. It is very similar to dalapon in chemical structure but differs in two functional characteristics. It has a longer period of soil persistence (3 to 6 months), and is not readily absorbed by foliage. It leaches readily and is absorbed by roots. At low rates of application it will kill annual grasses, and at 80 to 100 pounds per acre will kill perennial grasses. Example: TCA (Sodium TCA).

(3) Broadleaf and grass killers - Chemical compounds that are used for general long-term soil sterilization are the substituted ureas, substituted triazines, uracils, sodium borates, and sodium chlorate. These herbicides have a range of physical and chemical characteristics, and as a consequence, some of these materials work better under different soil and climatic conditions. In general, they are not absorbed by foliage but are readily absorbed by roots. They do not leach as far into the soil as those herbicides used for perennial broadleaf weed control. As a result, they are not very effective against these weeds. Most of these herbicides inhibit photosynthesis and death is the result of slow starvation. Germinating annual weeds die as soon as food material in the seed is exhausted. Sodium chlorate upsets respiration and carbohydrate metabolism. Boron is an essential element for plant growth at a few pounds per acre but is highly toxic at higher rates of application. These herbicides are used at low rates to eliminate annual weeds on noncrop sites for 1 or 2 years. If perennial weeds are present, higher rates of application are necessary. Examples: bromacil (Hyvar X), prometryne (Pramitol), monuron (Telvar), sodium chlorate, diuron (Karmex), sodium borates, and mixtures of these materials.

HERBICIDE FORMULATIONS

Most organic chemicals that are used for herbicides are not soluble in water. Consequently, in order to be useful, they must be prepared for convenient dispensing. Herbicides must be prepared so that uniform applications of as little as 1/8 pound per acre can be made.

Herbicides have been formulated as solutions (water or oil), emulsions, wettable powder, granules or pellets, and dusts. Often an emulsifier, spreader, sticker, or other surfactant is added to facilitate dilution and adhering capacity or to increase wetting of plants. Many formulations contain inactive fillers that serve as dilutents only. For example, there may be 2, 3, 4, or 6 pounds of active herbicide in a gallon of liquid formulation weighing as much as 10 pounds, or 4, 10, 20, 50, or 80 percent of active chemical in a granule, pellet, or powder formulation.

1. Solutions - A solution is a physical homogeneous mixture of two or more substances. Most water solutions can be seen through easily. Sugar or salt in water and amine salts of 2,4-D, 2,4,5-T, silvex, and other herbicides, form true solutions.

Most herbicide salts (a) can be dissolved in water and sprayed efficiently; (b) are not ordinarily soluble in oil; (c) should not be added to "hard water" because calcium and magnesium salts of 2,4-D may precipitate, clogging filters and sprayer nozzles; (d) agitation not essential as with other formulations; and (e) are not as active as equal rates of ester formulations.

2. Emulsions - An emulsion is formed when one liquid is dispersed with another liquid but the two materials maintain their separate identity. Milk and ester formulations of 2,4-D are common emulsions. These emulsions appear milky and are called the oil-in-water type. Small droplets of oil are surrounded by water. These emulsions have the same viscosity as water. If the oil droplets are large, the emulsions will separate rapidly. In water-in-oil emulsions, small drops of water are surrounded by oil and viscosity varies. Hair creams, mayonnaise, and herbicides that are prepared as invert emulsions of herbicides are examples of water-in-oil emulsions. Emulsions of herbicides are usually prepared when the organic chemical is soluble in oil but not water. If the proper emulsifying agents are added to oil containing an herbicide, an emulsion suitable for spraying can be made. Drift of spray particles is reduced with invert emulsions.

Emulsions (a) need agitation to prevent separation, (b) appear as milky solutions, (c) do not form precipitates, (d) are usually more active than equivalent amounts of salt, and (e) are difficult to remove from equipment.

3. Wettable powder - Wettable powders form suspensions consisting of solid particles dispersed in either oil or water. The proper surfactants must be added in order for wettable powders to stay in suspension. Wettable powder formulations are frequently prepared when the active ingredient is neither soluble in oil or water.

Wettable powders (a) require constant agitation to prevent solid particles from settling, (b) need large mesh screens to eliminate plugging, (c) cause abnormal nozzle wear, and (d) are usually not active through foliage as liquids.

4. Granules or pellets - Granules are chemicals applied in rates high enough so that the chemical crystals may be spread uniformly, or the chemical is spread by mixing with a "carrier" to provide enough bulk for even distribution. Clay, sand, vermiculite, and ground corn cobs are common carriers. Soil sterilants are frequently formulated as granules or pellets.

Granules (a) require no water or special equipment for application, (b) tend to fall off leaves of valuable plants without causing injury, (c) are convenient for isolated spot treatment, (d) may be easily moved by wind, (e) require water to dissolve and carry chemical into the soil, and (f) are more difficult than spray to apply uniformly.

5. Dusts - In the past, herbicides have been prepared as dusts, much the same as insecticides and fungicides. However, dusts are extremely susceptible to drift and are no longer used.

HERBICIDE CONCENTRATION

The container for each commercial herbicide has a label which states the amount of active chemicals contained in the particular product. This is expressed in percentage of active ingredient, acid equivalent, or phenol equivalent for solids; and in pounds per gallon for liquids. One of the best guides to use in purchasing a commercial herbicide is the price per pound of active chemical. When a formulation contains a mixture of herbicides, the amount of each herbicide is given on the label and should be considered in determining the relative value of the mixture.

Herbicide concentration varies. For example, 2,4-D may be purchased from 1 to 6 pounds per gallon. Consequently, it is very important to determine the active ingredient in any herbicide formulation. The acid of 2,4-D is usually formulated as an amine or an ester to make acceptable spray mixtures. In view of the fact that the acid is the toxic ingredient, 2,4-D, 2,4,5-T, and similar herbicides should be carefully checked for acid equivalent. If the formulation contains 4 pounds per gallon, 1 pound of acid will be contained in each quart. One pint is applied to an acre for a 1/2-pound-per-acre application. Liquid formulations are usually made upon basis of liquid volume.

Dry formulations are usually measured in dry weight and contain a certain percentage of active ingredient. For instance, Dacthal 50W contains 50 percent active ingredient. In order to apply 6 pounds of active ingredient per acre, it is necessary to apply 12 pounds of Dacthal 50W. Propazine 80W is an 80-percent formulation and 1¼ pounds of formulation are required to give 1 pound of active ingredient per acre.

HERBICIDE SELECTIVITY

A selective herbicide refers to a chemical that is more toxic to one plant than to another. This difference may be due to many factors and most important are:

1. Morphological differences in plants.
2. Absorption of the herbicide by the plant.
3. Translocation of the herbicide in the plant.
4. Physiological factors within the plant.

1. Morphological or structural differences - The directed spray takes advantage of a height difference among plants. Some plants are resistant to herbicides, because they have a waxy coating that will not allow herbicides to penetrate. Weeds, on the other hand, may be susceptible if they do not have this protection. Grass tends to have upright leaves, and does not intercept as much spray as plants with flat leaves. The amount of leaf surface area, due to leaf size or shape, also influences the amount of herbicide intercepted.

2. Absorption of herbicides - In order to affect a plant, herbicides must enter. Some plant surfaces absorb herbicides easily and other plant surfaces repel herbicides.

3. Translocation differences - In order for herbicides to be effective, they must not only penetrate into the plant but move to areas in the plant where they are effective. When herbicides are applied to leaf surfaces, the toxic material is usually transported upward or downward through the phloem. Soil herbicides are usually transported in the water stream in the xylem.

4. Physiological differences - As herbicides become more specific, physiological differences are accounting for a large part of selective toxicity. Herbicides upset various physiological processes involved in photosynthesis and respiration.

HERBICIDES IN SOIL

In order to be effective, herbicides applied to the soil must be at high enough concentration, where the seeds are germinating, to cause death. Frequently, selectivity of soil herbicides is based on the fact that herbicides are in the upper 1/4 inch of soil where weed seeds germinate. If the herbicide is toxic to both weeds and desirable plants, unwanted injury may occur.

Soil type and organic matter will affect herbicide performance. The toxicity of an herbicide is related to the concentration in soil water. Silty clay loam holds about twice as much available water as fine sandy

loam. Consequently, the amount of herbicide must be doubled on silty clay loam in order that the available soil water has a comparable concentration of herbicide. As the soil dries, it becomes more difficult for plants to absorb water. Consequently, under dry conditions the amount of herbicide that enters a plant is reduced, making the plant more tolerant. Also, as soil dries there is a greater tendency for herbicides to be absorbed by clay and organic matter.

The persistence of herbicides is affected by:

1. Microbial decomposition

2. Chemical decomposition

3. Adsorption to soil colloids

4. Leaching

5. Volatility

6. Photodecomposition

1. Microbial decomposition - Various soil fungi can utilize herbicides, as carbonaceous organic matter for respiration. Anything that affects micro-organism growth usually changes the rate of herbicide decomposition. Herbicides persist much longer under dry and cold conditions than when it is warm and moist. Frequently, addition of organic matter speeds herbicide breakdown.

2. Chemical decomposition - There are not many chemical herbicides that are susceptible to oxidation, reduction, hydrolysis, or hydration. Seasone is hydrolyzed into an active form of 2,4-D when it is placed in soil.

3. Adsorption to soil colloids - Herbicides are much like fertilizer and are rendered inactive when they are adsorbed on clay minerals or soil organic matter. Some herbicides are readily adsorbed and others are not. Treflan, a preemergency herbicide, is highly adsorbed and must be thoroughly mixed in order to be effective. Tordon is very soluble and readily leaches into the soil profile.

4. Leaching - The persistence of herbicides may be determined by leaching. Herbicides used for perennial weed control must leach into the soil where the weed roots are to be killed.

5. Volatility - All chemicals have a vapor pressure or have a tendency to evaporate. Evaporation of water is an example of volatility. Herbicides can be lost in the form of volatile gases. In some instances, herbicide volatility can be regulated by formulation. Ester formulations of 2,4-D volatilize easily compared to amine formulations.

6. Photodecomposition - Many herbicides are decomposed when subjected to ultra violet light from the sun. Monuron, diuron, and norea are very susceptible to this type of breakdown.

DRIFT AND VOLATILITY OF HERBICIDES

Most injury to susceptible plants is caused by drift and not volatility.

1. Spray drift is the lateral or upward movement of airborne spray particles that occur from the time that the droplets leave the spray jet until hitting the soil or plant surface. The amount of drift depends on (a) the size of droplets, (b) amount of wind, and (c) the height above the ground that the spray is released. The size of the droplets depend on the spray pressure, the size of the spray orifice, and the surface tension of the spray fluid. In order to minimize drift, sprays should be applied at low pressure (15 to 25 psi) and a high gallonage. When water leaves a spray nozzle under high pressure, a range of droplet sizes are formed ranging from 5 microns (fog) to 1000 microns (1/25 inch). The small particles will drift indefinitely in a still atmosphere. Operating large nozzles at a low pressure will result in particle sizes primarily from 500 to 1000 microns which are not very susceptible to drift.

If spray droplets are 1/50 inch (about the size of light rain), 1 gallon of spray per acre would apply 9 drops per square inch. These would drift 7 feet if released 10 feet above ground in a 3-mile-per-hour breeze. If 1/50-inch droplets were released in a 30-mile-per-hour wind 2 feet above ground, spray would drift 14 feet. Fog droplets in the same 30-mile wind would drift more than 6 miles.

In the past few years several methods of reducing drift have been attempted. The most advertised method has been with invert emulsions. Milk is an "oil-in-water" emulsion with a viscosity like water. Esters of 2,4-D make this type of emulsion and spray like water. If the emulsion is reversed or inverted to a "water-in-oil," it will be much more viscous and, with proper methods, can be sprayed in large droplets. Other methods of reducing drift are with shields, placing more nozzles on the boom, and markedly reducing pressure.

Inverted spray solutions produce a larger droplet that will remain in the air a shorter period of time and thus be affected less by wind and temperature. Larger droplets require a larger volume for adequate coverage, but the increased cost is usually more than offset by the greater safety.

2. Spray volatility is the tendency of a sprayed material to vaporize or give off fumes after it has hit the soil or plant surface. Volatility, because of the small amount of material involved, can only be a hazard where extremely sensitive plants are nearby. Volatility can only be controlled by reducing the vapor pressure (tendency to vaporize) of the chemical. The herbicide 2,4-D is the only one causing appreciable economic crop damage from volatility. White crystals of

2,4-D amine are not volatile, while ester formulations have varying degrees of volatility depending on the length or weight of the alcohol used to make the ester of 2,4-D. Butyl, ethyl, methyl, and isopropyl esters of 2,4-D are very volatile and should not be used. Isooctyl, butoxyethyl, and propylene glycol are examples of ester formulations which are called low volatile and do not vaporize easily. However, all forms of amines are less volatile.

Esters are made by combining the parent chemical with an alcohol and are usually named for the alcohol from which they are made. The ester, an entirely new compound, is produced by a chemical reaction of the alcohol and the acid. Most esters are not water soluble. They are [redacted] ordinarily applied as emulsions.

Water soluble amine formulations are prepared by dissolving chemicals such as 2,4-D and 2,4,5-T in a solution of amine and water. Although high volume ground applications have been successful, low volume aerial amine applications have given erratic results.

In attempts to reduce volatility damage, emulsifiable acid concentrates and oil-soluble amines have been formulated. Parent acids made soluble, then emulsified to go into water are known as emulsifiable acid concentrates or free acid formulations. For the oil-soluble amine, the herbicide is in an oil phase which is emulsified in water. The ability to spray an amine with oil often increases its effectiveness up to that of an ester formulation.

CALCULATIONS FOR HERBICIDE APPLICATIONS

Recommended rates of herbicide application are stated in ounces or pounds per square rod, 1000 square feet, or acre, where the area to be treated can be measured. Where spot spraying of individual or small clumps of plants is necessary, or where dense foliage of brush or trees is to be thoroughly wet, the concentration of spray is usually recommended in pounds of active chemical per 100 gallons of water or oil. Recommended rates should not be exceeded since this is not only uneconomical but for translocated herbicides particularly, may result in top destruction without a permanent plant kill.

To determine the amount of herbicide formulation required per acre, per 100 gallons, or for a total area, use the following calculations:

1. For liquid formulations

$$\frac{\text{Rate or amount required in pounds}}{\text{Pounds of herbicide per gallon}} = \text{gallons required}$$

$$\frac{\text{Rate, 2 pounds per acre}}{\text{4 pounds per gallon}} = \text{0.5 gallon}$$

$$\frac{\text{Concentration, 4 pounds per 100 gallons}}{\text{4 pounds per gallon}} = \text{1 gallon}$$

$$\frac{\text{Amount required, 24.3 pounds}}{\text{2 pounds per gallon}} = \text{12.15 gallons}$$

2. For granule or pellet formulations

Use the same calculations as for liquid formulations, except use pounds of active herbicide per pound of formulation (percent ÷ 100) instead of pounds per gallon.

Examples:

$$\frac{\text{Rate, 2 pounds per acre}}{\text{0.5 pound (50\% material)}} = \text{4 pounds}$$

$$\frac{\text{Concentration, 4 pounds per 100 gallons}}{\text{0.5 pound (50\% material)}} = \text{8 pounds}$$

$$\frac{\text{Amount required, 24.3 pounds}}{\text{0.20 pound (20\% material)}} = \text{121.5 pounds}$$

HERBICIDE SAFETY

Many herbicides are irritating or potentially dangerous, but they are not hazardous if used properly and recommended precautions are heeded. The best safety approach is to rigidly follow label instructions regarding herbicide use, handling, storage, needed protective clothing, care of equipment, and disposal of containers. The same applies to grazing treated areas, livestock use of treated water, control of chemical entry into streams or lakes, and drift control. Human exposure is through the skin, respiratory system, or orally. Most herbicides have a low acute oral toxicity, compared with many insecticides or other pesticides. A few are highly toxic to humans, livestock, and wildlife, and some are toxic to fish.

The relative toxicity to mammals is given on the following page for some of the most commonly used herbicides. Degree of toxicity is based on LD_{50} ratings (lethal dose that kills 50 percent of the experimental animals).

Toxicity Rating	Class	LD_{50} (mg./kg.)	Probable Lethal Dose for 150-lb. man
1	Extremely toxic	less than 5	A taste (less than 7 drops)
2	Very toxic	5 to 49	7 drops to 1 teaspoonful
3	Moderately toxic	50 to 499	1 teaspoonful to 1 ounce
4	Slightly toxic	500 to 4,999	1 ounce to 1 pint (1 lb.)
5	Almost nontoxic	5,000 to 14,999	1 pint to 1 quart
6	Nontoxic	15,000 and above	more than 1 quart

RELATIVE TOXICITY OF HERBICIDES TO MAMMALS

Common Name or Designation	Some Common Trade Names	LD_{50} mg./kg.	Toxicity Rating
Sodium arsenite	Atlas A. Triox	10	2
DNBP	Sinox, Dow General	30	2
Paraquat	Paraquat	157	3
Gasoline		--	3
2,4,5-T	Various brands	300	3
Copper sulfate	Various brands	300	3
Diquat	Diquat	400	3
Silvex	Kuron, Weedone-TP	500	4
2,4-DB	Butyrac, Butoxone	500	4
2,4-D	Various brands	500	4
MCPA	Various brands	700	4
Aspirin	(For comparison)	750	4
Dicamba	Banvel-D	1,040	4
Linuron	Lorox	1,500	5
AMS	Ammate	1,600	4
2,3,6-TBA	Tryben, Benzac	1,644	4
Atrazine	Atrazine	3,080	4
Table salt	(For comparison)	3,320	4
Diuron	Karmex	3,400	4
Monuron	Telvar	3,500	4
Amitrole-T	Amitrol-T, Cytrol	5,000	4-5
Simazine	Simazine	5,000	4
Bromacil	Hyvar X	5,200	5
Fenuron	Dybar	6,400	5
Picloram	Tordon	8,200	5
Dalapon	Dowpon	9,300	4
Sodium chlorate	Atlacide	12,000	5
Amitrole	Amino Trizole, Weedazol	15,000	6

FIVE RIGHTS FOR HERBICIDE USE

1. Use the RIGHT herbicide

   Label tells what plants it will control and how to use it safely.

2. On the RIGHT target plant

   Choose the herbicide recommended for the specific plant(s) to be controlled.

3. At the RIGHT time

   Observe label precautions on grazing.

4. In the RIGHT amount

   Calculate correctly the amount needed - follow mixing directions.

5. The RIGHT way

   Adjust and operate equipment properly. Control drift and contamination.

TERMS

1. Acid equivalent - The theoretical yield of parent acid from an active ingredient.

2. Active ingredient - The chemical compound in a product that is responsible for the herbicidal effects.

3. Biodegradable - Capable of being broken down by micro-organisms or other biological systems.

4. Carrier - The liquid or solid material added to a chemical compound to facilitate its application in the field.

5. Concentration - The amount of active ingredient or acid equivalent in a given volume of liquid or in a given weight of dry material.

6. Contact herbicide - An herbicide that kills primarily by contact with plant tissue rather than as a result of translocation.

7. Diluent - Any liquid or solid material serving to dilute an active ingredient in the preparation of a formulation.

8. Emulsifying agent - A surface active material which facilitates the suspension of one liquid in another.

9. Emulsion - The suspension of one liquid as minute globules in another liquid; for example, oil dispersed in water.

10. Epinasty - Increased growth on upper surface of a plant organ or part (especially leaves) causing it to bend downward.

11. Growth regulator - An organic substance effective in minute amounts for controlling or modifying plant processes.

12. Nonselective herbicide - A chemical that is toxic to plants generally without regard to species.

13. Phytotoxic - Poisonous to plants.

14. Selective herbicide - A chemical that is more toxic to some plant species than to others.

15. Soil sterilant - An herbicide that prevents the growth of plants when present in the soil. Soil sterilization effects may be temporary or relatively permanent.

16. Spray drift - The movement of airborne spray particles from the intended area of application.

17. Surfactant - A material which facilitates, and accentuates the emulsifying, dispersing, spreading, wetting, and other surface-modifying properties of herbicide formulations.

18. Suspension - A system consisting of very finely divided solid particles dispersed in a solid, liquid, or gas.

19. Synergism - Cooperative action of different chemicals such that the total effect is greater than the sum of the independent effects.

20. Translocated herbicide - An herbicide which is moved within the plant from the point of entry.

21. Vapor drift - The movement of herbicidal vapors from the area of application.

22. Volatile - A compound is volatile when it evaporates or vaporizes (changes from liquid to gas) at ordinary temperatures on exposure to the air.

HANDY REFERENCES

1. Chemical Weed Control Handbook. Cooperative Extension Service, College of Agriculture, Washington State University, Pullman, Washington. Revised annually. Cost - $2.25.

2. Herbicide Handbook of the Weed Society of America. Dr. F. W. Slife, Business Manager, WSSA, Department of Agronomy, University of Illinois, Urbana 61801. Cost - $3.

3. Weed Control: As a Science by G. C. Klingman, John Wiley & Sons, Inc., New York. 1961.

4. Principles of Plant and Animal Pest Control, Volume 2, Weed Control. National Academy of Sciences, Washington, D. C. 1968. Cost - $8.

5. Pesticide Handbook - Entoma. 18th Edition, 1966. D. E. H. Frear, College Science Publishers, State College, Pennsylvania. (Published annually. Available from College Science Publishers, P. O. Box 798, State College, Pennsylvania 16801. Paper bound $3, cloth bound $4.50. Standing orders for each annual edition are accepted.)

6. Chemical Control of Range Weeds. USDA-USDI, Supt. of Documents, Washington, D. C. 1966. Cost - $.30.

7. Suggested Guide for Weed Control, 1967. Agricultural Handbook No. 332, USDA, Agricultural Research Service. Supt. of Documents, Washington, D. C. Cost - $.40.

8. Herbicide Manual for Noncropland Weeds. USDA, Agricultural Research Service, in cooperation with Department of Navy, Bureau of Yards and Docks. Issued March 1965. Supt. of Documents, Washington, D. C. Cost - $.50.

9. Montana Weed Control Guide. Cooperative Extension Service Circular 1081. Issued annually.

10. Clinical Handbook on Economic Poisons. Public Health Service Publication No. 476, Revised 1963. Supt. of Documents, Washington, D. C. Cost - $.55.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE